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Redefining the Small Craft Advisory for Hazardous Seas

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A. Background

Customer feedback and forecaster excursions on the ocean have shown that the current 10 foot criteria for issuing a Small Craft Advisory for Hazardous Seas (SCAHS) does not truly reflect hazardous conditions. On the Pacific Ocean, 10 foot or higher swell with long periods produce gentle rolling seas that pose little, if any, threat. Conversely, a relatively low 6 to 8 foot sea with a short period can produce very hazardous conditions. For a discussion supporting this assertion and the relationship between wave steepness and hazardous conditions, see Appendix A.

Figure 2 Study Area - WFO Eureka Area of Responsibility

B. Procedure

Experienced mariners report that hazardous conditions exist when seas are "square", that is when height and period are about equal. For example, 7 feet at 7 seconds. The relationship is not linear. A 20 foot by 20 second wave is not steep while a 7 foot by 7 second wave is very steep. Therefore, steepness must be computed mathematically. The National Data Buoy Center computes wave steepness on their webpage. The steepness is a function of significant wave height (hs) and the peak frequency, (fp) the frequency with the highest energy. It is computed, in part, using the formula below.

$A = e^{(-3.3 * \ln(fp))}$

If hs > A / 250, steepness = "very steep"
If hs > A / 500, steepness = "steep"
If hs > A / 1000, steepness = "average"

C. Data

Observations from NOAA Buoys 46022 and 46014 were collected from July 1, 2001 to December 31, 2001. During that period a log was kept of when small craft advisories were issued and whether they were wind based or wave based. A wave steepness was computed based on the swell height and period in the Coastal Waters Forecast. Wind based advisories superceded all wave based advisories. The buoy observations were averaged in 12-hour blocks and compared to the actual advisories issued and the steepness-based advisories. Buoy 46022 was used for zones 450 and 470 with Buoy 46014 used for zones 455 and 475. The probability of detection (POD), false alarm ratio (FAR), and critical success index (CSI) for wave based advisories were calculated for each zone. While buoys report significant wave and not swell, for periods when winds were below small craft advisory levels the significant wave is a close approximation to swell.

$$POD = \frac{Correct\_Advisories}{Total\_Events} \qquad FAR = \frac{Incorrect\_Advisories}{Total\_Advisories}$$

$$CSI = \frac{Correct\_Advisories}{Total\_Events + Incorrect\_Advisories}$$

D. Criteria

The revised criteria for the Small Craft Advisory for Hazardous Seas (SCAHS) is as follows. All waves less than 5 feet are not considered hazardous. For waves 5 feet or greater but less than 18 feet, steepness values of "steep" or "very steep" are considered hazardous. All waves 18 feet or greater are considered hazardous.

SCAHS Criteria	
Wave Height	Hazard Level
H <5 feet	Not hazardous
5 feet ≤ H < 18 feet	Steep or Very Steep are hazardous
H ≥ 18 feet	All hazardous

1 Revised Hazardous Seas Criteria

E. Detailed Explanation of Criteria

The revised criteria for the small craft advisory for hazardous seas is predominately based on the National Data Buoy Center steepness equations using wave height and

period.

If tall waves do not meet the steepness criteria they necessarily have long periods. Long period waves interact with the sea floor at significant distances off shore resulting in increased wave steepness. The steepest wave of the sets present or forecast will be used to determine if an advisory is needed. For example, the wind wave has a steepness of "average" while the 16 foot swell is "steep" - an advisory would be issued.

The steepening of the long period waves occurs when the wave speed becomes bottom dependant. When a wave feels the bottom, it slows down but period is conserved. That causes the wave to steepen. For example, an 18 foot wave will begin to be dominated by the bottom in about 650 feet of water for periods that do not meet the calculated steepness criteria (~16 seconds).

The 18-foot criteria was chosen because very high waves also have hazards which are not associated with steepness. For example, the wind differential between the crests and
troughs of very high waves can be significant enough to affect vessel handling. Also, the troughs of very high waves can expose sea floor hazards which normally remain submerged.

F. Criteria Comparison

During the period of the study, small craft advisories for hazardous seas using the 10

Zone 450	10 foot	162
	Steepness	167
Zone 470	10 foot	142
	Steepness	147
Zone 455	10 foot	122
	Steepness	127
Zone 475	10 foot	102
	Steepness	107

2 Number of Forecasts by Zone

foot criteria and the steepness criteria were verified using buoy observations. Comparisons were only made when both criteria were available and a small craft advisory for wind supercedes either seas criteria. All periods with either a gale or storm warning were not used.

Forecasts were evaluated as a verified advisory, missed event, unverified advisory, or a correct forecast of no event. Table 3 gives the verification statistics. An advisory was considered correct if the observed steepness from the corresponding buoy was either "steep" or "very steep". A total of 528 comparisons were completed.

% Both Verified	28
% Both Missed Event	17
% Both Unverified	7
% Only 10 ft Verified	4
% 10 ft Correct with Null	10
% Steepness Verified	21

3 Comparison and Verification Statistics

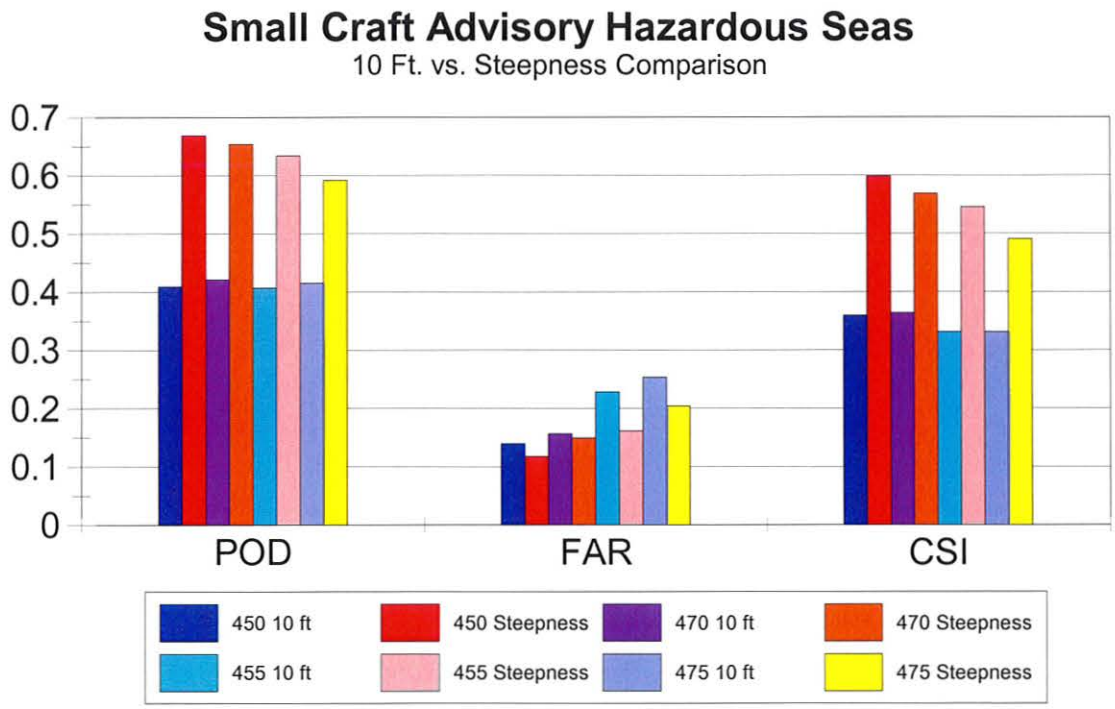
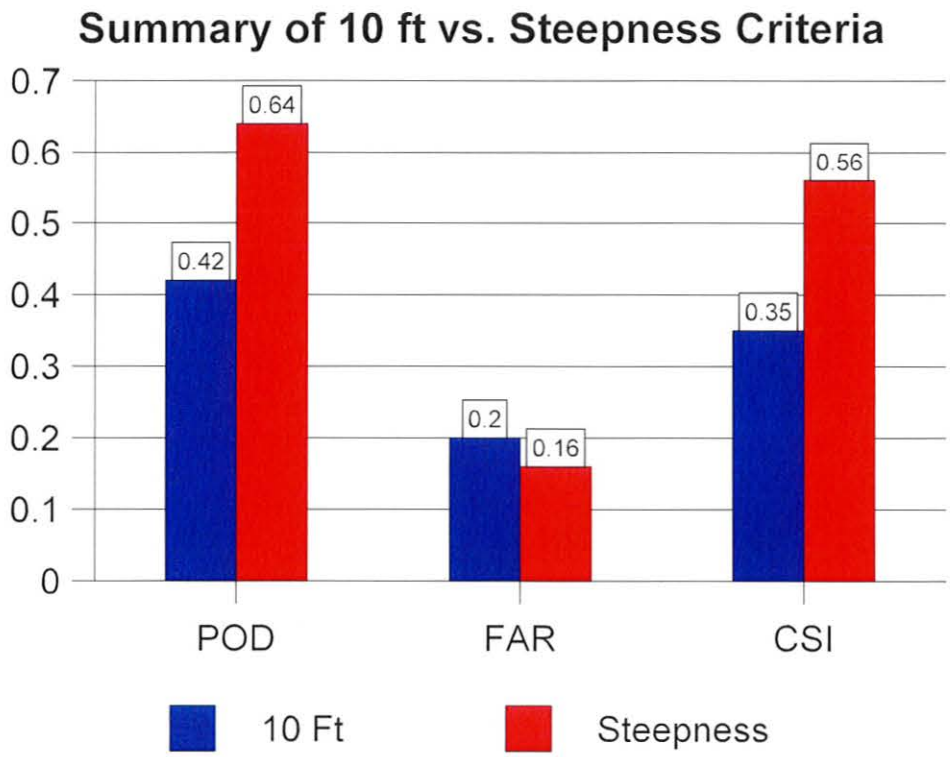


Figure 3 Verification Statistics

G. Summary

The surface of the ocean is complex with many different wave trains interacting at any given time. Mariners face many hazards including the danger of swamping, pitch poling, or capsizing in heavy seas. The hazard of waves is in part determined by the steepness of the wave face. Identifying hazardous seas purely by wave height ignores this fact.

Using a steepness criteria significantly increases the probability of detection for hazardous sea conditions while reducing unnecessary advisories for larger but benign conditions. These improved statistics will increase customer confidence in the small craft advisory for hazardous seas. The higher probability of detection will keep mariners in port during hazardous events, thereby reducing their exposure to risk. The lower false alarm rate will allow increased marine activity since captains will embark and not remain in port during benign conditions. The revised criteria fulfills two parts of the National Weather Service mission - to save lives and property while enhancing the national economy. Mariners will have less risk while increasing their economic activities.



H. References

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APPENDIX A

The Relationship Between Wave Steepness and Vessel Size

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The argument to change the criteria for Small Craft Advisory for Hazardous Seas is based on the assertion that wave steepness is preferable over wave height as an indicator of hazardous conditions for small craft. The difficulty lies in defining exactly what is a small craft and what constitutes hazardous conditions. The subjectivity of these two terms should not stop the National Weather Service from trying to improve the criteria for hazardous sea conditions in a way that is meaningful for the majority of craft using this product. Marine safety professionals were asked to first identify some common characteristics of small craft and second to correlate these characteristics with sea conditions that lead to hazardous conditions.

There is no legal definition of small craft but some general criteria have been proposed by Michael Carr, instructor at the Marine Institute of Technology & Graduate Studies. He suggests that a small craft is non self-bailing, non self-righting, potentially underpowered, and posses a relatively high center of gravity. These characteristics cause a craft to be particularly sensitive to the steepness of waves as shown by the following scenarios:

1. An open decked craft making headway directly into steep waves can be swamped by the wave crests breaking over the bow and/or by plunging the bow into the base of the wave after leaving the wave crest. Swamping frequently leads to capsize because of the loss of stability resulting from the boat being full of water.

2. An under powered craft making headway into steep waves can capsize by stalling out at the wave crest. When this happens, the craft can be pushed backwards into an end over end capsize known as pitch poling. Conversely, an adequately powered craft can become air born after leaving the crest of a steep wave and capsize in mid-air which causes the craft to land in the water upside down.

3. Any craft traveling in roughly the same direction as the waves tends to accelerate down the face of each overtaking wave. These accelerations can become great enough in steep waves to cause the craft's bow to plunge into the base of the wave. When this happens, the craft may veer into a broadside orientation to the wave and capsize. This is known as broaching. Alternatively, when the bow plunges into the base of the wave, the craft can capsize end over end without veering. This is known as pitch poling (see 2 above). Both of these mechanisms are exacerbated by the high center of gravity typical of small craft.

4. A craft with a high center of gravity becomes progressively more unstable at severe angles of heel, leading ultimately to a point at which the buoyancy of the hull form actually induces capsize. Steep waves taken broadside can cause a

craft to achieve this critical angle and result in capsize. It is important to note that the center of gravity of a craft tends to go up as the size of the craft goes down. This is because the weight of the occupants becomes proportionally greater for smaller craft, and unless they are laying in the bottom of the boat, their center of gravity is quite high.

5. Any craft, but particularly those with characteristics of small craft, can experience motion in steep waves that can cause occupants to fall overboard.